New York, New Haven and Hartford Railroad,
Automatic Signalization System
Along the shoreline of the Long Island
Sound between Stamford and New Haven
Stamford (and New Haven)
Fairfield (and New Haven) Counties
Connecticut

HAER No. CT-8

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Mid-Atlantic Region
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HISTORIC AMERICAN ENGINEERING RECORD

New York, New Haven and Hartford Railroad, Automatic Signalization System

HAER No. CT-8

Location:	On the New Haven Line, along the shoreline of the Long Island Sound between Stamford and New Haven, Fairfield and New Haven Counties, Connecticut
Date of Construction:	1917
Present Owner:	Consolidated Rail Corporation
Present Use:	Railroad signalization system
Significance:	This system is one of the few automatic semaphore signal installations still in use on a major railroad in the United States. It was a major element in the first large-scale application of high-voltage railroading in the United States.
Project Information:	The Connecticut Department of Transportation, with Federal assistance, plans to undertake a program of re-electrification and signal replacement in this section of the New Haven line The project will include retirement of the Cos Cob power generating station, conversion of the power supply and transmission system equipment from 25 cycle to 60 cycle operation, and replacement of the present block and interlocking signals and signal equipment from just west of Stamford to New Haven. Under Section 106 of the National Historic Preservation Act of 1966, mitigative documentation was undertaken in 1982 by John S. Noble and Louis Kurtessis, historians.

HISTORY

New Haven line electrificaton was part of the movement of our society into the overall age of electrification. At the time this project was being planned, we were changing from the Victorian age of horse-drawn vehicles and kerosene and gas lighting to powered vehicles and electric lighting. The steam locomotive had been developed to a high degree technically and provided almost all of the long distance transportation in this country. The steam locomotive was a technological marvel in its day, but they had certain drawbacks for the train passengers and for areas adjacent to the right of way. The smoke, gases, dust and cinders generated by a coal-burning locomotive became a major irritant to passengers and to persons who had to live or work alongside a railroad route.

The undesirable side effects of coal-burning steam locomotives were especially noticeable in built-up urban areas. Also, the rapid growth of electrified trolley cars began to present a serious competitive situation for the New York, New Haven and Hartford Railroad in the early 1890s. In response, the railroad management began planning for electrificaton of sections of the system. By June 30, 1895, electric operation began on a nine-mile-long rail branch in Massachusetts. This was the first example of electric power applied to steam railroad operation in this country. It proved to be practical and economical. The steam road from Stamford to New Canaan, Connecticut, was electrified soon thereafter.

Due to the drawbcks of coal-burning steam locomotives, the New York State legislature on May 7, 1903, passed a law that required that the Grand Central Terminal in Manhattan, and approaches within the limits of the city of New York, should, within approximately five years, be operated with some form of motive power not requiring combustion. The only practical response to this requirement was the conversion to electric operation. This occasioned one of the most notable examples of technological planning, design and construction in the history of this country.

The New York Central Railroad, whch owned the trackage in the area involved, chose to extend its electrification beyond the limits prescribed by the Act to a point above Woodlawn Junction. This meant that the segment of the line between Grand Central Railroad and Woodlawn Junction, over which the New Haven Railroad also operated, would be equipped for direct current operation, and the New Haven would therefore have to adopt a traction system compatible with that of the New York Central.

The New Haven Railroad similarly took the view that it was desirable to extend the required electrical traction area to Stamford, Connecticut, which at that time was the outer limit of its suburban district. It was also decided that the electrification of this small portion of the New Haven system would be done in such a way as to provide for future developments and extensions of the electrical system.

Once these basic decisions had been made, design and construction of the new system proceeded quickly. An 11,000 volt, single-phase alternating current system was installed between Woodlawn and Stamford, and the first New Haven electric train to Grand Central was operated from New Rochelle, New York, on July 24, 1907. Electric operation reached Stamford by October of that year. Electrificaton of the main line eastward to New Haven was begun in 1912, and trains were operating under catenary to New Haven by June 1914. The remaining main line electrification to Cedar Hill (East Haven) was completed in the following year.

An author stated in a railway magazine of that time, "The (New Haven) railroad is to be congratulated upon having done thoroughly well the task undertaken, and upon giving the first great demonstration of high-voltage railroading upon this side of the Atlantic."

SIGNALIZATION OF THE ELECTRIFIED NEW HAVEN LINE

The signal system, installed as part of the electrification of the New York Division of the New York, New Haven & Hartford Railroad, was undoubtedly one of the most extensive, single, signal systems in the world.

The entire automatic signal system, furnished with power from a generating plant at Cos Cob, Connecticut, extended from Sunnyside Yard in the Pennsylvania System on Long Island, to and including the classification yards at Cedar Hill, New Haven, with branches from New Rochelle Junction to Woodlawn, New York.

The 700 kva of energy from the generators at Cos Cob was distributed over 132 miles of power lines and 24 miles of power cables along 89 miles of railroad, having 344 miles of signaled track. The signal power was transformed by 1,718 transformers, ranging from 20 kva to 225 kva, in connection with the operation of 940 track circuits, 1,215 signal arms lighted by 1,215 high-powered electric lights, and 133 electrically-operated switch units. There were 36 interlocking stations with 1,245 working switch levers; and, in connection with which, there were 709 storage battery cells floated across 11 motor-generators, all of which were connected together by 175 miles of low voltage, aerial cable. The consumption of energy for the signal units ranged from 700 watts for a switch motor, down to 0.144 watts for a tower indicator.

Automatic train control systems for public safety were in wide use throughout the United States during the early 1900s, and the automatic block and interlocking signal information system on the New Haven road represents the type of system commonly installed in that period. However, two important factors regarding the New Haven signal system are of historic interest.

1. The automatic signal system, installed in 1917, was one of the first such systems installed on an electrified railroad in the United States. From the following detailed description of the system, it can be seen that operation of automatic signals on electrified railroads presented certain unique problems in separation of motive power from signal power, requiring the use of special electrical technology. It is reasonable to assume that such technology was developed for, and first used on, the New Haven line.

2. A great number of the originally electrified railroads which may have had signal systems comparable to that on the New Haven electrified section have been converted to the use of diesel motive power, and it is likely that their signal systems have been modified. It is reasonable to assume that the New Haven signal system was the last one of its age to remain largely as originally installed between Stamford and New Haven.

Therefore, the system as a whole is of considerable historic interest and importance in American railroad development. It follows that some of the components installed at the time of the original installation are also of historical significance in railroad engineering. Although many of the devices used in the early electrical power and control systems, such as switches, transformers, coils, relays, capacitors, etc, have been improved in efficiency and design, the basic technology remained essentially unchanged. However, two of the components of the New Haven signal system, namely the semaphore signals and the centrifugal and vane type relays, have not been manufactured in many years, and the devices that replaced them are greatly different in design and operation. The semaphore structures in particular, as specially designed and installed inverted (semaphore below the signal mechanism) on the New Haven catenary structures, were not used in this manner on any other major railroad in the United States.

FUNCTIONAL AND OPERATIONAL CHARACTERISTICS OF THE SIGNAL SYSTEM

The signal system chosen was an automatic block system, consisting of a series of track circuits which control, at appropriate locatons, automatic signals. One block control overlapped the next, so as to provide advance information to the approaching engineman.

Insulated joints in the rails established the limits of each block, or separate track circuit. A motor-driven signal was located at the entering end of the block and the circuit for the operation of the signal was designed to allow three types of signal indications. The signal used was the General Railway Signal Company Model 2A, designed in 1908. An elevation view of this semaphore signal supported from a catenary bridge is show on page .

Basically, the signal apparatus consisted of a metal case mounted on a catenary bridge, which contained a three-position signal relay, or controller, and a motor and mechanisms for transmitting the rotation of the motor to a steel rod connected to the signal display at the bottom of the apparatus. This signal display consisted of a metal casting, called a spectacle, to which a red and white, short, wooden blade as attcached. A more detailed description of the signals is given in a following section.

The signal system had separate functions, with independent signals and controls for each functon:

- Automatic block signals were controlled by the trains on the line and permitted only one train to occupy one block at a time. These were identified by V-tipped semaphores.

- Home and distant signals at the interlockings were controlled by the tower operator to permit converging and crossover train movements. These were identified by round-tipped semaphores.

- Dwarf signals were located within interlocking areas where crossover train movements occur. They were used to govern reverse movements through an interlocking area, necessary during local switching movements. They usually displayed only two aspects, Stop or Restricting.

- Drawbridge signals were operated by interlocking controls at the moveable bridges to protect trains at the bridge approaches. These were identified by square-tipped semaphores.

The system was designed so that a failure (loss of power, a broken rail, equipment defects, human error, stray electric currents, etc.) would cause certain signals to display a "stop" indication, with no possibility of a false "clear" signal which could result in a serious accident.

Fundamental to the capability of the signal system to perform the intended signal functions accurately and reliably was the electrical segregation of the signal system circuits from the motive power circuits. The circuits of both systems made use of the train running rails at the same time, and it is possible that without separation the motive power system could have influenced the signal system to produce a false signal indication. It had also been demonstrated that the 11,000 volt, alternating current, motive power circuits could electrostatically induce current flow in nearby circuits.

A.C. motive power as generated at 25 cycles. To achieve isolation of the signal system, signal power was generated at 60 cycles A.C. from separate generators at the Cos Cob plant. The track circuit relay would operate as intended, permitting current to flow in the signal circuit, only when both relay coils were energized with 60 cycle current. Operated at 25 cycles, the relay was not sufficiently energized to close the signal circuit, and the signal display remained at "stop" position.

Block Signals. The purpose of the automatic block signal system was to insure safety to passengers and railroad personnel by virtually eliminating the possibility of collision of two trains. The signal system was designed and operated to permit only one train to have exclusive use of a track section or block, not less than 2,000 feet in length, as long the train occupied that section. Nearly all malfunctions of a control element would cause a signal to return to, or remain at, "stop" position. The operation of the system was fundamentally dependent upon the track circuit mentioned above. A source of 60 cycle electrical energy was connected across the rails at one end of each section and at the other end was a precision electrical relay which controlled an electrical switch in the signal circuit.

When there was no train or rolling stock on the track, current flowed along one rail, through the relay, and back through the other rail. With the track relay thus energized, certain contacts were held closed, permitting current from the signal transformer to flow in the signal control circuit. Any interruption of current in the track circuit resulting from a broken rail, loss of track circuit power, component failure, etc., or short circuiting of current to the relay caused by a train in the block, de-energized the relay and opened the relay contacts to prevent current flow in the signal circuit. The signal controlled by the circuit then dropped from a less restrictive to the "stop" position. The block control circuits overlapped such that the conditions in each block were transmitted to the next block behind (with respect to train direction) to give advance information to the following train. That is, if a block was occuppied, or a malfuction occurred, the signal at the entering end of the block displayed "stop" (red lens, semaphore horizontal), and the signal at the entering end of the following block indicated "caution" (yellow lens, semaphore at 45 degrees). The second block behind, and those following, were unaffected and displayed "clear" (green lens, semaphore straight up).

Interlocking Signals. The interlocking signals operated much the same as the open line block signals, except that the tower operator could also operate the signals within the interlocking by changing track switch positions to allow converging or crossover train movements. Any change in switch position was automatically accompanied by an appropriate signal display which would notify a train operator within or approaching the interlocking to proceed or wait. The interlocking mechanism prevented the operator from allowing two trains to occupy or approach the same track at the same time.

Dwarf signals, located within interlocking areas, were mounted at track level, and the signal display consisted of a small spectacle of two lenses, to which was attached a short, square-tipped semaphore blade. Because they were used to govern reverse movements, they were designed to be observed by a trainman stationed at the rear of the train. Also because they governed switching movements, the trains were operated at low speeds past them.

Drawbridge Signals. Drawbridges are movable structures installed to carry railroad tracks over navigable streams, and a definite section of track is operated out of position at times to allow boat passage or clearance. Signal systems are always provided to govern train operation over these movable sections of track. Two fundamental rules for design of drawbridge signal systems are:

(1) It must be impossible to initiate operation of the bridge with signals governing movements over the bridge if the signal display an aspects other than "stop".

(2) It must impossible to "clear" the signals unless the drawbridge is properly lined up and locked, and the rail junctions lined up and locked.

In order to insure that the above safety requirements are met, interlocking of the drawbridge controls and the drawbridge signals is accomplished either at a tower controlling adjacent crossovers, or at a separate control tower on the bridge.

Power System

The power for the operation of the entire signal system was furnished from motor-generators located in the power plant at Cos Cob. There were three 450 kva, 2300 volt, 60 cycle generators, driven by 25 cycle induction motors. Any two or all three units could be operated in parallel to furnish current for the signal system. The 60-cycle current was taken single-phase from the frequency changers at 2300 volts and transferred to 11,000 volts at an outdoor substation located at the Cos Cob power plant.

The signal transmission system consisted of duplicate circuit, 11,000 volt, single-phase lines extending east and west from Cos Cob. Facilities were provided at most of the interlocking towers for sectionalizing both of the transmission lines, which were supported on the catenary structure on either side of the right-of-way. The tower operators, under the direction of the Load Dispatcher, were in a position to cut in or out of service any section of the signal transmission line. Between New Haven and South Mount Vernon, the signal load was connected to both transmission lines through automatic switches, so arranged that the signal load was normally taken from one set of feeders. By energizing that set of feeders, the load automatically cut over to the duplicate service, and then automatically restored to the original source when that line was again energized. All of the oil circuit breakers for sectionalizing the supply lines were of the Westinghouse remote control type, and the system was thoroughly protected with electrolytic lightning arresters.

DESCRIPTION OF THE MODEL 2A SIGNAL

The Model 2A signal, which was chosen for the New Haven Line signal system, was designed and manufactured by the General Railway Signal Company of Rochester, New York. Movement of the signal display was accomplished by a high-torque, low-speed motor and a train of gears connected to the semaphore spectacle. Earlier types of power signals had been found to be unreliable and required excessive maintainence and operation costs.

Model 2A was a refinement of early electrically-operated signals. It provided a mechanism that could be used as high or dwarf signals, as an automatic, semi-automatic or non-automatic signal. It would also give the desired indications in the upper or lower, right or left hand quadrant, and could be arranged to operated on high or low voltage, and on alternating or direct current.

The initial Model 2A was designed for top-of-mast operation. This design allowed the installation of the motor and operating mechanism at the same level as the signal face. The principal advantage of this type of installation was mechanical efficiency, due to the direct connection of the mechanism to the semaphore shaft. The same basic elements were modified to produce a base-of-mast mechanism. In this arrangement, a crank, which replaced the shaft coupling in the top-of-mast signal, changed the rotational movement of the motor to an "up and down" motion transmitted through a rod to the signal face. The use of base-of-mast mechanisms was favored in areas of extreme climatic conditions, so as to provide easier access to the mechanism for inspection and maintenance.

On the New Haven line, the Model 2A was modified to allow for the suspension of the signals from the catenary bridges. This was a unique feature of the New Haven line signal installation, because most railroads mounted the signals on top of the supporting structure. One reason for the use of the suspended signal was to ensure good visibility to the train operator. Another interesting feature of these semaphore signals was the shortness of the blades. This was necessary to provide adequate clearance for the pantographs attached to the top of the electric locomotives and cars.

A double signal includes two separate motors and mechanisms mounted within cast-iron cases attached to the top of the catenary bridge. Two steel drive rods were located within a six-inch diameter, 13'6" long hollow pipe signal support. The signals operated completely independently. The signals are shown in the "stop" position. The linkage was arranged so that a downward movement of the drive rod raised the semaphore arm and lens casting (spectacle) to a less restrictive display. In most installations of this type, the rod exerted an upward force to clear the signal. Electrical energy was required to hold the signal in the less restrictive positions. A loss of power caused the semaphore to return by gravity to a "stop" position.

The arrangmenet of components within the mechanism case is shown on page . The weather-tight case provided protection against the elements for the components within. The motor operated in a dust-proof case of its own, which had a hinged door with a simple fastening, that could be quickly opened for inspection. The motors operated on alternating current and were of the 2-phase induction type, arranged to operate on a single-phase supply by means of a reactance unit. The reactance unit was connected in a series with one of the stator windings, in order to obtain the necessary phase displacement. Both stator windings were in service while the motor was operating, which eliminated the necessity of contacting devices. Stator windings are ordinarily used with single-phase motors to interrupt the current through a starting winding, after the motor has developed normal speed.

The method of retarding the signal arm, as it fell by gravity to the caution or stop position, was accomplished electrically in the following manner. The motion of the falling signal arm was transmitted, by means of the train of gears, to the motor which was operated in the reverse direction. Just before the signal arm reached the caution or stop position, the motor was short-circited through a snubbing resistance, by means of proper circuit controller contacts, which effectively checked the speed of the mechanism, so that the signal parts and semaphore arm were brought to rest without shock. This arrangement reduced to a minimum the number of operating parts, and was superior to the previously used dash-pot, which had been the source of numerous cases of trouble.

The circuit controller was the brain of the Model 2A signal mechanism, as it controlled the operation of the motor and signal. It consisted of a frame, which carried a hardwood cylindrical drum in which the contact plates were mounted; adjustable contact fingers with an arrangement for locking them in proper position; an attachment for producing snap contacts, when required; and gear sectors, by means of which the movement of the main shaft was transmitted to the circuit controller. There was space for a maximuum of fourteen contacts, each of which could be adjusted to make or break at any position of the signal arm.

The signal display, which was attached to the pipe support, consisted of a cast-iron spectacle, to which was attached a short wooden blade, painted red with a white strip across it. The shape of the white stripe conformed to that of the blade tip, i.e., V-shaped, round or square. The wooden blades were so short that they extended only a few inches beyond the metal casting. The length of these blades are in marked contrast to those on other railroads, many of which were 3' 6" in overall length. As was mentioned earlier, the short blades provided clearance for the pantographs on top of the electric cars.

DESCRIPTION OF THE ELECTRICAL RELAYS

There were two basic types of electro-mechanical relays which were essential elements controlling the automatic signal circuitry. One was the track relay (centrifugal frequency type), the other was the line relay (vane type). These were precison devices encased in sealed, glass-sided enclosures. The relay elements consisted of a small electric motor, movable metal mechanisms and electrical contacts.

The centrifugal frequency track relay was the heart of the automatic signal system. Its basic role in the signal circuit was described briefly in the secton Functional and Operational Characteristics of the Signal System. This type of relay included a small two-phase induction motor. One phase of the motor was energized from the local bus at the signal location, by 60-cycle signal power, while the other phase was energized by current from the track. The track circuit carried both 25-cycle tractor current, and 60-cycle signal current. The purpose of the relay was to permit activation of the signal circuit only when both phases of the relay motor were energized with 60-cycle current. The track relay was operated when a train shunted the track circuit.

This was accomplished within the relay by a revolving member directly connected to the rotor of the two-phase motor. The member included two weighted arms which were lifted by centrifugal force when the rotor turned. When the motor was operated by 25-cycle current, the centrifugal force was not sufficient to lift the connterweight and close the electrical contacts. Thus, the traction power currents in the track circuit were not able to cease operation of the signal system. However, when the 60-cycle signal power was flowing in the track circuit, the motor turned at a speed sufficient to cause the relay contacts to close. This allowed the track signals to move from a "stop" indication to a "caution" or "clear" indication.

This relay not only had the advantage of being the safest type of relay, but also took the major part of the required energy from a local bus, and only a small part from the track. Therefore, it was comparatively economical in its consumption of energy.

The role of the three-position line relay was to govern the signal indication, between zero or "stop"; 45 degree or "caution"; and 90 degree or "proceed." The line relay was located in the signal circuit between the bus bar supplying 110 volt current and the signal mechanism. The signal mechanism, described earlier, was provided with a combination of contacts arranged to allow the signal to display the "stop," "caution" or "proceed" indications. The position of these contacts controlled the polarity of energy to a line circuit which included the three-position line relay.

The line relay was designed with two coils. One was permanently energized from the local bus and the other from the line circuit. The line circuit passed through the contacts of the track relay and, as mentioned above, was subject to change in polarity. When the line phase was de-energized by the opening of the track relay contacts, the moving member, or vane, of the line relay assumed a position by gravity, so that neither the front nor the back contacts were closed. This interrupted the circuit to the signal mechanism which in turn, by gravity, assumed the "stop" indication. When the line relay was energized in one polarity, it closed two contacts through which the energy from the bus was transmitted to the signal mechanism and caused the signal to display the 45 degree indication or "caution." With a change of polarity of the line circuit, the moving vane reversed its position, thereby closing three contacts to the signal mechanism, which then displayed the 90 degree, or "proceed" indication.

The relays used on the New Haven line were designed and manufactured by the Union Switch and Signal Company, whose general office and works were located in Swissvale, Pennsylvania. This company was founded by George Westinghouse in 1881, and held the patents on the Westinghouse system of electro-pneumatic block signaling and interlocking, as well as other appliances for railway protection.

The plates were included in a catalog published by the Union Switch and Signal Company in June 1911. In the preface to the catalog, the company confidently stated that "No order will be too large for our shop facilities to guarantee satisfactory deliveries, or too small for our careful attention." The order placed by the New York, New Haven and Hartford Railroad, as part of their electrification program, was undoubtedly a large one.

The relays still in use on the New Haven line in 1981 was manufactured during the early 1900s. This longevity was due to good design and construction, and to meticulous maintenance throughout the years by railroad shop people.

CATENARY BRIDGES

General

The overhead catenary suspension system which carried the power supply, or trolley, lines over each track was suspended by catenary bridges which spanned the four or more tracks, generally at 300-feet intervals along the line. In addition to this primary function, the catenary bridge structures carried the power transmission lines, auxiliary power lines, electrical section switches, and the overhead train control signals. The span section of a typical structure was constructed of twin trusses connected by horizontal members at top and bottom. The upper and lower chord members were structural steel angles and the truss diagonals were flatbars or, in the case of heavier trusses, steel angles. The span structure was supported by square or tapered posts or, for heavier structures, A-frames, placed and bolted on concrete foundations. The supports were fabricated of structural steel angles and bars similar to those used in construction of the span.

The catenary bridges over the entire mainline were of two basic types: intermediate bridges and anchor bridges. Intermediate types were placed at 300-foot intervals on the mainline to provide immediate support for the continuous catenary and power distribution cables, and for overhead signals. Anchor bridges were located at two-mile intervals. These were of considerably heavier construction, designed to withstand the "pull" of the wires when catenary sag adjustments are made, and to support the heavy electrical section switching gear carried on these bridges.

Since catenary construction between Woodlawn, New York, and Stamford preceded construction east of Stamford by nearly seven years, the designs of the catenary bridges varied somewhat between the two sections. Additionally, because of the variations in the lengths of spans, load characteristics, clearances, and other imposed conditions, the dimensons, details, design of members, etc., varied slightly in structures of the same type in each section.

The bridges were designed by the New Haven Railroad engineering division and the Westinghouse Electric Manufacturing Company.

New York Line to Stamford

The catenary system from Woodlawn to Stamford was constructed between 1905 and 1907. There were 151 intermediate bridges and four anchor bridges on the six-mile section between New York State line and Bridge 399 just east of the Stamford section.

Intermediate Bridges - Intermediate bridges consisted of two supporting side posts and a horizontal truss. Each supporting post was approximately

38 long by 1 foot, 10 inches square, and was composed of four angles secured together by lacing bars. Each post rested on a foundation which contained about nine cubic yards of concrete. Anchor bolts extended entirely through the concrete foundation and held the base of the post to the foundation. The cross truss was attached by means of the bolts to the vertical posts, allowing a distance of 23 feet 4 inches from the lower side of the truss to the top of the rails. The truss was 4 feet 6 inches deep by 1 foot 10 inches wide.

The side posts were extended upward and were utililzed for supporting power wires, which were carried on steel angle cross-arms bolted to the posts. The lower arm carried two insulators, the inner one of which supported the pass feeder, while the outer carried an auxiliary supply. The upper cross-arm carried two wires of a subsidiary three-phase circuit. The third wire of the three-phase circuit was carried on a light vertical channel iron support.

Anchor Bridges - Anchor bridges of especially heavy construction were placed every two miles and the catenary cables were anchored against these bridges. The typical four-track anchor bridge consisted of two A-shaped posts, having a span at the base of 15-feet and a width at right angles to the track of about two feet. These posts were also extended above the truss for the purpose of carrying the pass-feeder wires. The truss was bolted to the side posts, and was 4 feet 6 inches deep by 5 feet wide. The anchor bridges also carried lightning arresters, transformers for operating the circuit breakers, foot walks, hand railings, lighting circuits, and the wire and conduit for the auxiliary control circuits. The anchor bridges were secured to concrete foundations by means of long anchor bolts. Each post rested upon two concrete blocks, each contaning about two cubic yards of concrete in the case of the four track bridge. Photographic documentaton was made of the anchor bridges at Cos Cob and South Norwalk as part of this submission.

Circuit Breakers on the Anchor Bridges

The most visible pieces of equipment supported by the anchor bridges were the automatic circuit breakers, by means of which different sections of track could be electricially isolated. Also, the several parallel tracks could be electrically separated from one another in case of an accident to any one track.

In order to minimize the effect of faults in the overhead power system upon train operations, current-limiting resistances were installed at Cos Cob. In case of overload, these resistances, normally short-circuited, were first automatically cut into the circuit, after which an 11,000 volt control circuit were energized, supplying tripping power to the circuit breakers located on the anchor bridges.

The main conductors over the running tracks were paralleled throughout their entire length by two feeder wires. These feeders constituted auxiliaries to the main track conductors, and were connected with the latter at each anchor bridge through the circuit breakers. These auxiliary feeders provided the means for feeding around any one section in case it was cut out of service due to some accident in that particular section.

Control wires were carried in iron conduit and lead-covered cable from the circuit breakers to the adjoining signal tower, where a switchboard was provided. This panel was fitted with switches so that any circuit breaker coud be tripped by hand, or closed by the attendant in the signal tower.

Stamford to New Haven

Except for an experimental section near Glenbrook (immediately east of Stamford) installed in 1909, catenary construction and electrification of the 39-mile mainline between Stamford and New Haven commenced in 1912 and was completed in 1914. There were approximately 650 intermediate and 19 anchor bridges in this section.

Except for minor modifications, usually made for carrying of additional electrical and signal devices, the catenary bridges on both the Mainlne and the New Canaan branch remain as originally installed.

Catenary Bridges on Other Roads

A research of railroad electrificaton in the United States indicates that overhead bridges were used on several railroads for supporting catenary power lines or for the mounting of signals. Overhead bridges are still in use on roads other than the New Haven. In addition, overhead signal bridges may be in use on several of the non-electrified roads, including the former Penn-Central system line, Southern Pacific and Santa Fe in California, and the Texas and Pacific Railroad.

Historical Significance

Truss bridges spanning the tracks have been used by a number of electrified railroads to support electric distribution lines and signals, and by a number of non-electrified roads as signal bridges. However, the New York, New Haven and Hartford Railroad was a pioneer in the use of these structures as the sole type of support for overhead power line feeders on a high-speed, heavy traffic, long-distance roads. The stability and long life of these structures have been a significant factor in the reliability and durability of New Haven's catenary system, which has been in use for nearly 70 hears without modification or replacement.

The bridges, intermediate bridges in parrticular, were not unique or particularly significant in terms of engineering achievement or historic interest. Structures of this type have a wide application in bridge and building construction, and in heavy industrial uses. However, these structures, in providing a stable, maintenance-free, and long-life method of supporting overhead catenary, increased the reliability of the total system, and are of historic significance in representing an advancement in the development of railroad electrification technology in the early 1900s.

TABLE I

TRUSS-TYPE OVERHEAD BRIDGES

	Original Railroad	When Electrified	Purpose of Bridge	Abandoned
1.	Baltimore & Ohio (Howard St. Tunnel Baltimore)	1885-1902	A	1902
2.	New York Central (Hudson & Harlem Div.)	1906-1913	B	Still in use
3.	Pennsylvania (New York to Washington, D. C. and Philadelphia to Harrisburg, PA; Sunnyside Yards, N.Y.C.-1910)	1915	B	Still in use
4.	St. Clair Tunnel Company (Detroit, MI.)	1908	A	1958
5.	Boston & Maine (incl. Hoosac Tunnel, MA.)	1911	A	1946
6.	Long Island (New York)	1905-1970	B	Still in use
7.	Southern Pacific (Oakland-Berkeley, CA)	1911	B	1941
8.	Staten Island Rapid Transit (New York)	1925	B	Still in use (third rail)
9.	Illinois Central (Chicago, IL)	1926	A,B	Still in use
10.	Boston, Revere Beach & Lynn (Boston, MA)	1928 (trolley)	A	1940
11.	Delaware, Lackawanna & Western (New Jersey)	1930-1931	A,B	Still in use
12.	The Reading Company (Pennsylvania)	1931,1973	A	Still in use
13.	Cleveland Union Terminal (New York Central & Nickel Plate Railroads)	1930	A	1953

Note: A - power catenary support
B - signal mounting

Source: When Steam Railroads Electrified, William D. Middleton, 1974

SWITCH TOWERS AND INTERLOCKING SIGNALING

This description of the switch towers and interlocking signaling is included because the long-range plan for improvement of the New Haven West End commuter service calls for replacement of existing obsolete switch-operating and control equipment with electrically-powered mechanisms. The design and operation of switch and signal interlocking is a complex process, and only the basic elements can be described here.

At crossings, junctions, drawbridges, or at any point where a great number of switches are situated in one limited locality (terminals, yards and other points of routing), it is often necessary to have the switches controlled from one central point, in order to govern train movements over the switches by the use of fixed signals and to "interlock" the various functions in such a way that their movements must succeed each other in a predetermined order. The interlocking mechanism prevents the operator from allowing two trains to occupy or approach the same track at the same time.

In order to achieve this, towers are built at the principal points of switching activity to house the machinery used by the tower operator to accomplish the necessary switching. Most of the switch towers on the New Haven line between the New York State line and New Haven are still equipped with the original mechanical interlocking "machines." A mechanical machine consists of large, floor-mounted levers connected to square steel bars, which are connected to round steel pipes, running parallel to the tracks. Each steel pipe is connected to a track switch. Thus, the force exerted on the lever by the operator is transmitted mechanically through the linkage described, and eventually shifts the movable parts of the track switch.

Obviously, where the distance from the tower to the switch is great, a considerable amount of effort is required on the part of the tower operator. In some cases, two men are required to move the lever. It is rather surprising that these mechanical switching "linkages," of which art of which has been exposed to the elements for 64 years, are still operable.

Interlocking

Mechanical interlocking is accomplished by a locking bed composed of two groups of bars at right angles. Each bar of the one group is connected to a particular lever and carries projections, known as dogs, which engage with projections on the bars 90 degrees from it. The latter bars are called "cross locking." If the cross locking can be moved, the lever may be thrown. The lever may not be thrown if projections on the cross locking interfere with projections on bars operated by other levers. Thus, a form of mechanical interference is arranged, so designed that conflicting routes may not be set up, nor conflicting signals displayed. Also, a check is given that the levers for any possible route are all in the proper position when that route is set up.

Signal Interlocking

The mechanical locking beds described above provide locking between control levers only. The control levers control the operation of the track switches and, in checking conditions in the track ahead when it is desired to display a signal authorizing a train movement, it is important to first check the position of the switch on the ground. This is done by the use of switch-repeating relays. Contacts on the switch-repeating relay are used in series with the lever contacts in the control of an electric lock applied to the switch control lever.

This requires the track switch and its control lever to be in correspondence before the electric lock is energized and the final motion of the lever is allowed. Thus, the release of the mechanical locking between the switch control lever and other levers is withheld until indication is received that the intended operation of the switch has been properly accomplished.

A display board located above the lever assemblage shows the track arrangement within the interlocking area. It contains small colored lights which come on when a train passes any of the signals controlled by the tower operator. It provides the tower operator with a visual indication of track occupancy within this area.

Tower Communication Facilities

The tower operator receives instructions from a centrally-located train dispatcher who coordinates the actions of the several tower operators within the dispatcher's particular territory. The New Haven line between New York City and New Haven is controlled by two dispatchers. One dispatcher is responsible for that section of the line from the New York terminal to a point west of the South Norwalk interlocking area. The other dispatcher controls the area from that point to New Haven.

Communication between the dispatchers and their respective tower operators is conducted through leased telephone lines. The tower operator also has the capability of voice communication with the engineer on a train within the area controlled by his tower. This communication is achieved by short-range radio equipment.

A third system of communication available to tower operators is the ConRail dial telephone system. This way, ConRail personnel can make calls to many points within the system. For example, field personnel can make calls to tower operators by using telephones on railroad station platforms.

Description of Switch Tower Structures

The buildings which house the switching equipment at various interlocking areas vary in condition, but they are all old. They are located close to the tracks, and the operating area is located on the second floor to afford the tower operator good visibility of the tracks in his immediate area. They are of brick and frame construction, and the interior furnishing is minimal. The three sides of the building toward the tracks contain many windows, the shades show their age.

The artificial lighting is provided by bulbs hanging from the ceiling, only a few have conical shades. The towers area is usually manned by just one person, but the operators have voice communication with operators of passing trains. Heating is by hot water radiators and airconditioning by opening the windows.

Some of the towers in the less important interlocking areas are manned part-time, while the major towers are operational 24 hours a day.

BIBLIOGRAPHY

Arthur, William, "An Important Development in Steam Railroad Electrification," The Electric Journal, 1914

Describes advantages of the single-phase electrification system used on the New Haven line, and a system alteration made during the extension from Stamford to New Haven. The alteration eliminated electro-magnetic disturbances in neighboring telegraph and telephone circuits.

General Railway Signal Company, G.R.S. Model 2A Signal Handbook 2, December 1918, Reprinted August 1950.

Provides technical descriptions and illustrations of various forms of the Model 2A power signal used on the New Haven line. Contains many drawings of the electric motor mechanisms and semaphore spectacle. Also includes maintenance instructions.

McHenry, E. H., "Heavy Electric Traction on the New York, New Haven & Hartford Railroad," Street Railway Journal, August 1907.

Description written by the Vice President of the New York, New Haven and Hartford Railroad on the electrification system chosen for the New Haven line. Provides technical and economical reasons for choice of this system. Followed by a detailed description of the equipment installed to implement the system. Includes pictures and details of anchor bridges, trolley hangers, circuit breakers and other elements of the overhead electrical system.

________________, "Electrification of the New York, New Haven & Hartford," The Railroad Gazette, August 16, 1907.

Another description by Mr. McHenry of the electrification system and its advantages over alternate systems. Includes a detailed description of the electric locomotives designed and manufactured for this project; also a description of the Cos Cob power plant.

Middleton, William D., When the Steam Railroads Electrified, Kalmbach Publishing Company, 1974

A comprehensive description of the history of electric railroading in the United States. Includes chapters on the electrification of Grand Central Terminal and the New Haven line. Many photographs.

Phillips, Edmund J., Railroad Operation and Railway Signaling, Simmons-Boardman Publishing Corporation, 1953.

A practical handbook of illustrated questions and answers that explains the what, why and how of railway signaling and train operation. Describes in detail types of fixed signals, track circuits, the block system, interlocking signaling, centralized and automatic train control.

"The Installation of Electric Traction on the New York Terminal Section of the New Haven Railroad," Engineering News, September 5, 1907.

An illustrated article describing all aspects of the electrification system on the New Haven line, including the Cos Cob power plant.

Tri-State Transportation Commission, Equipment and Roadway Improvements for the West End New Haven Railroad Commuter Service, by Louis T. Klauder and Associates, 1967.

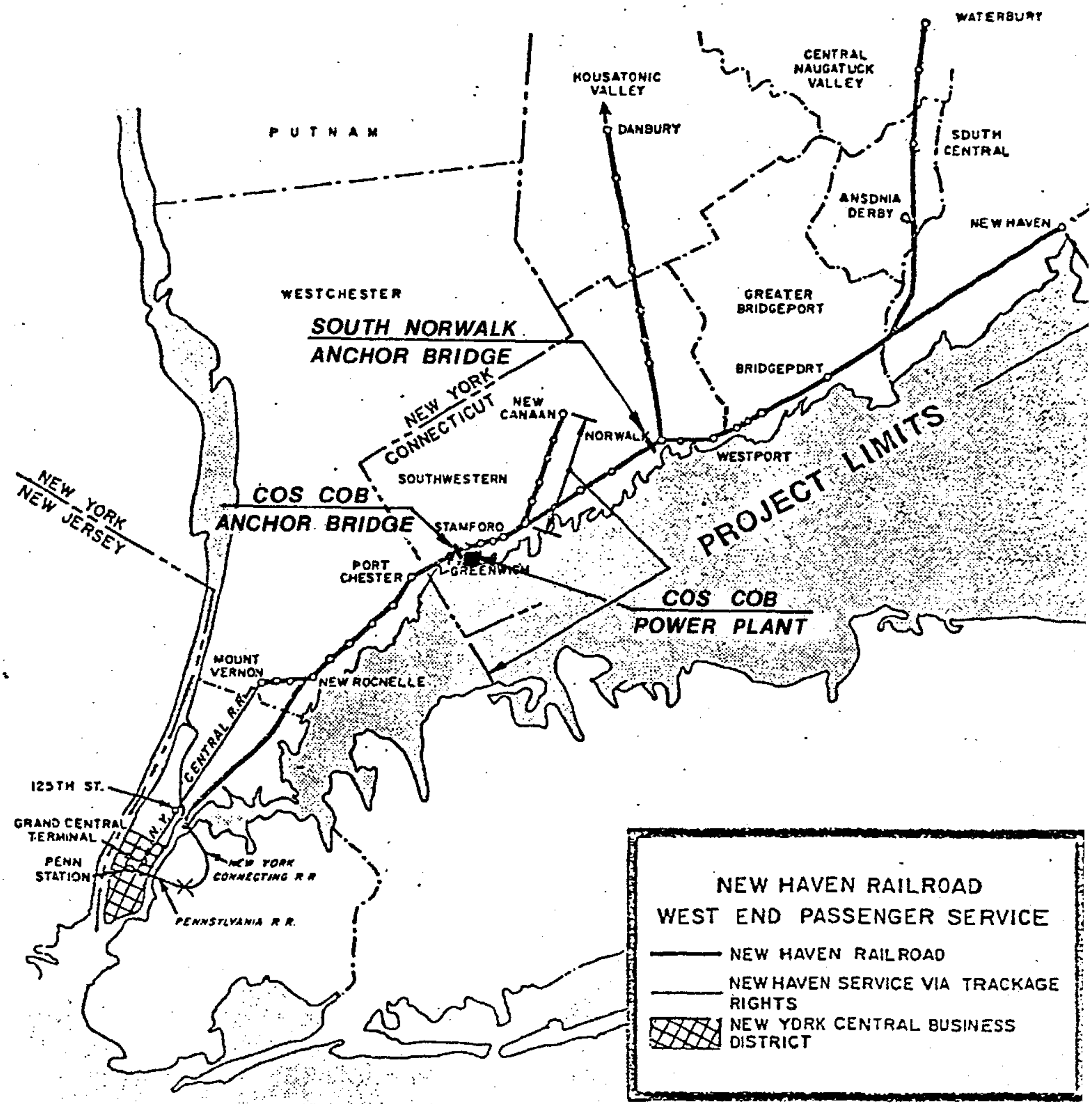
Recommendations for physical improvements to the New Haven facilities included in the West End commuter service area from New York City to New Haven. One major element is the replacement of most of the existing signal system with cab signal and train control systems. This was the basis for the program for re-electrification and signal replacement instituted by ConnDOT, which required the documentation of the existing signal system.

Union Switch and Signal Company, Alternating Current Apparatus Catalogue, Section H, 1911.

A sales catalogue containing beautifully drawn plates and brief descriptions of all the elements of the signalling apparatus manufactured by the company. Includes information on the vane type and centrifugal frequency relays used in the signal system of the New Haven line.

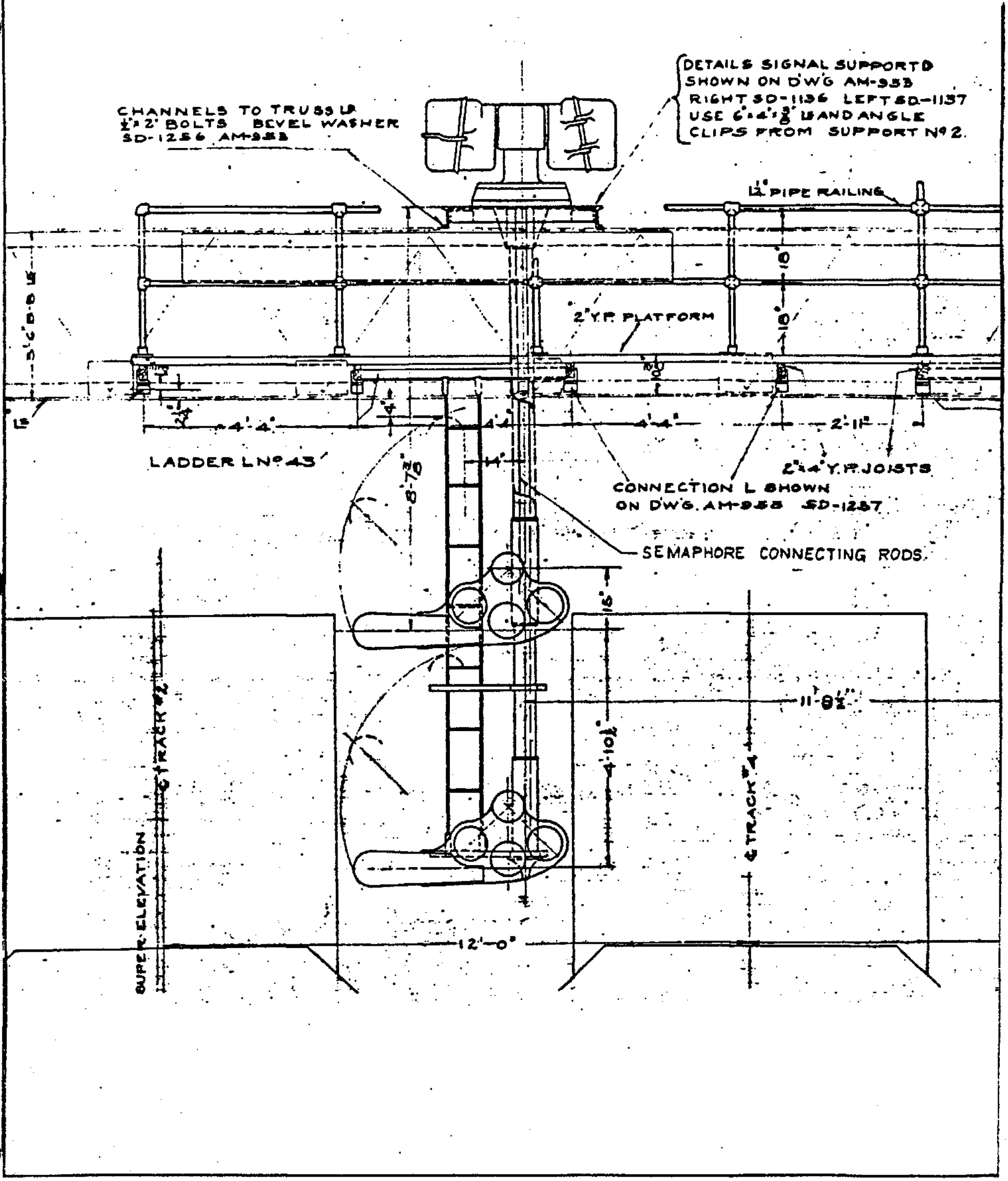
Westinghouse Electric and Manufacturing Company, New York, New Haven & Hartford Railroad Electrification, Special Publication 1698, June 1924.

An excellent description of all aspects of the electrification of the New Haven line. Written for both the technical and non-technical reader. Includes a section on the signal system. Many photographs and diagrams. Original copy in the Science and Techology Department, Carnegie Library of Pittsburgh. Prepared by the company that designed and manufactured the electrical equipment and locomotives for the new system.



LOCATION MAP

Figure



TYPICAL SEMAPHORE SIGNAL

N. Y. N.H. & H. Railroad

Figure 2

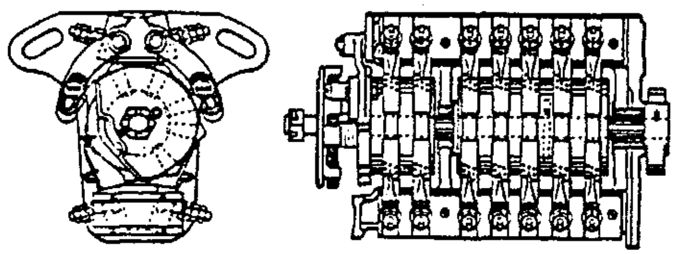


FIG. 7. MODEL 2A CIRCUIT CONTROLLER

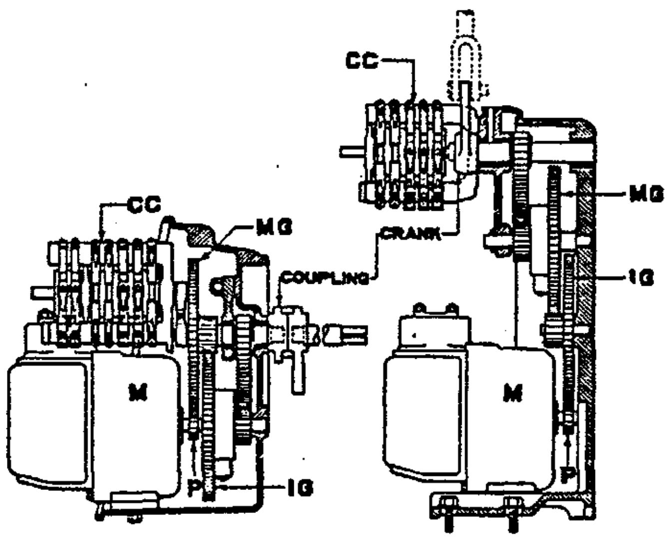


FIG. 6. COMPARISON OF TOP-OF-MAST AND BASE-OF-MAST MECHANISMS
CC Circuit Controller — MG Main Gear
IG Intermediate Gear — P Motor Pinion
M Motor

MODEL 2A SIGNAL
MECHANISM DETAILS

N.Y. N.H. & H. Railroad

Figure 3

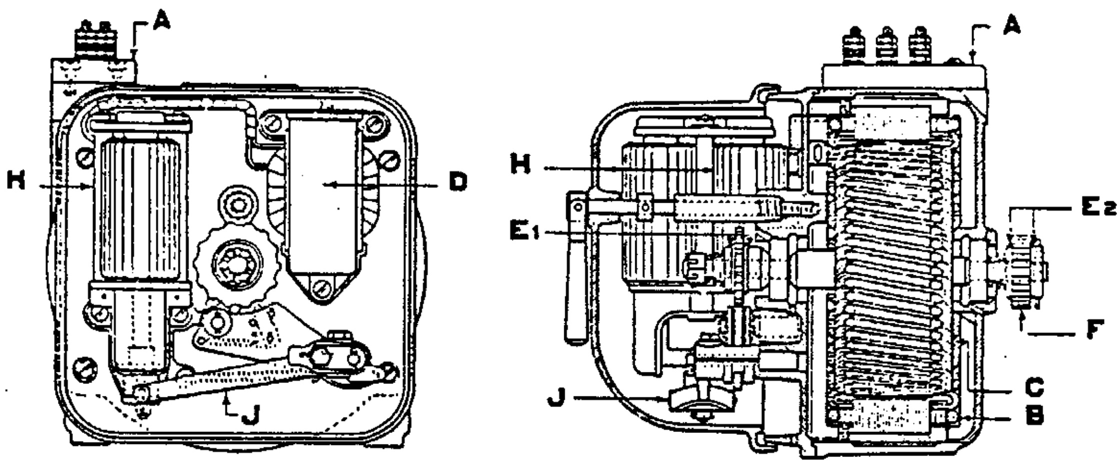


FIG. 16. 110-VOLT, A-C. INDUCTION MOTOR, 25- AND 60-CYCLE

A Terminal Block
B Stator
C Rotor
D Impedance
E_1-E_2 Friction Disks
F Motor Pinion
H Hold-Clear Coils
J Hold-Clear Armature

MODEL 2A SIGNAL
MOTOR DETAILS

N.Y. N.H. & H. Railroad

Figure 4

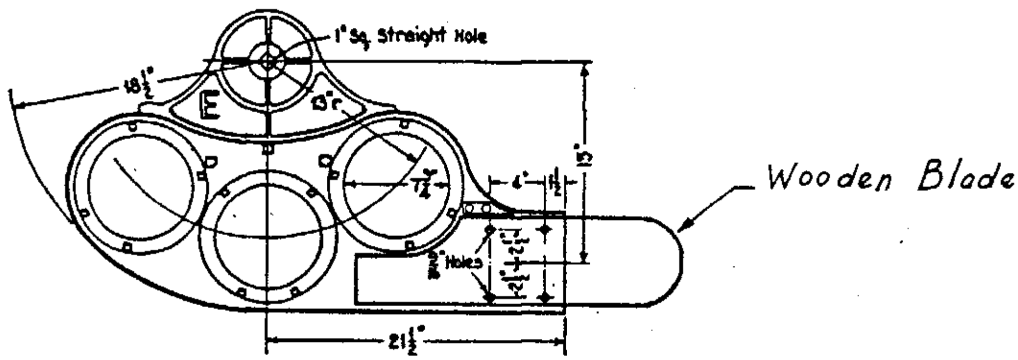


FIG. 28. SEMAPHORE SPECTACLE
R. S. A. Design "A" Drawing 1040, dated May, 1913

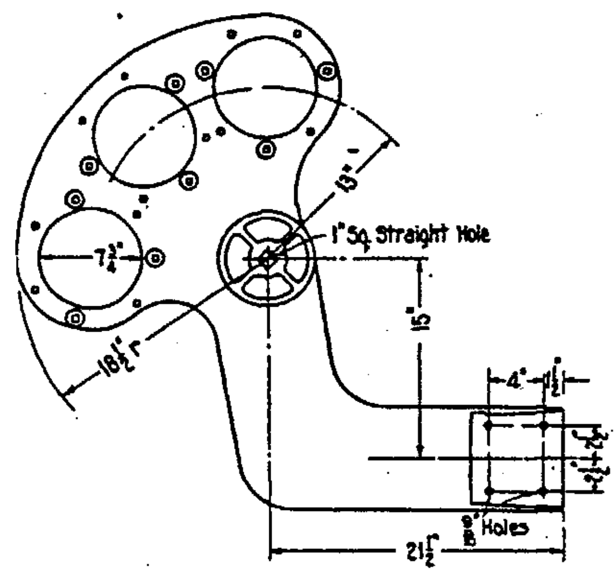


FIG. 29. SEMAPHORE SPECTACLE
R. S. A. Design "B" Drawing 1041, dated May, 1913

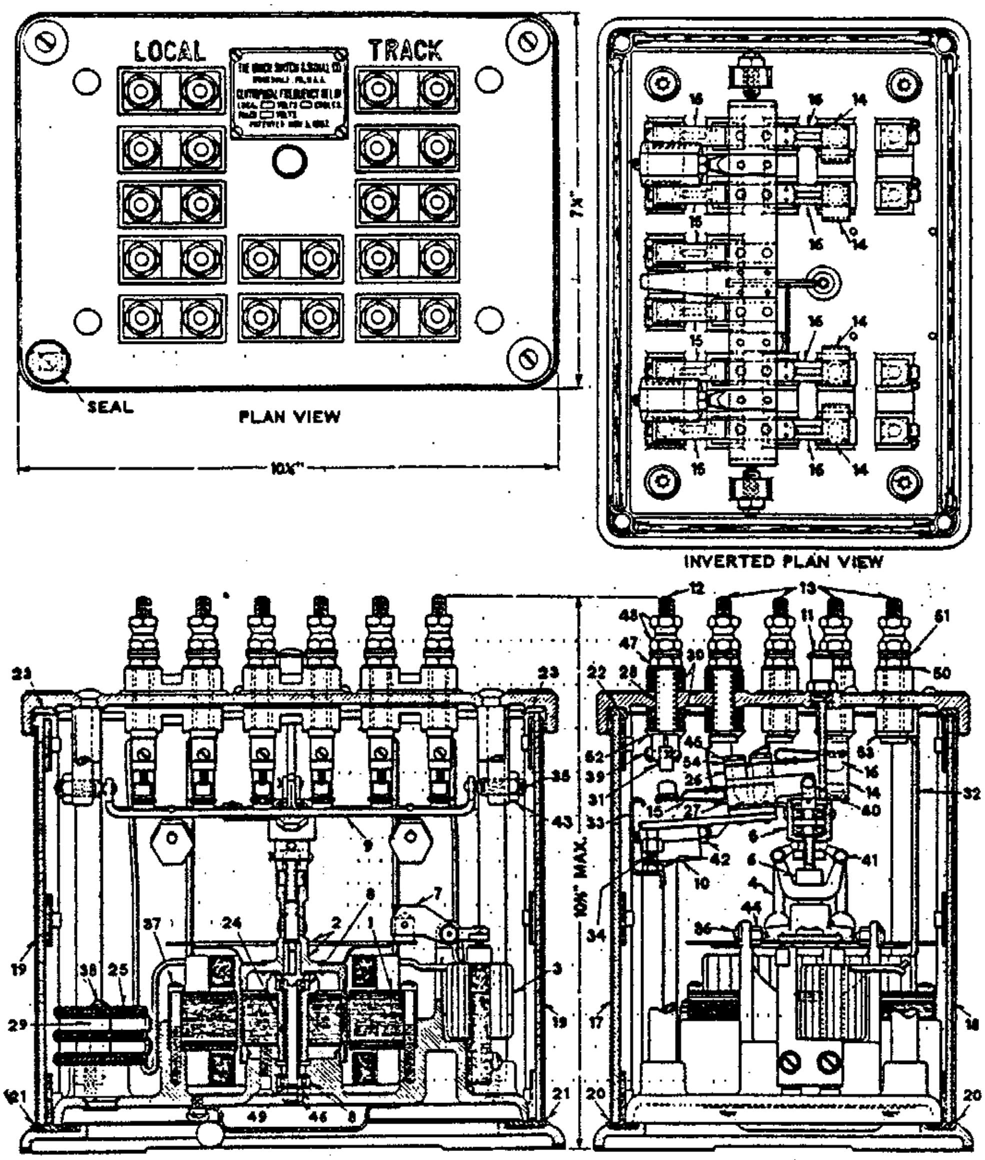
MODEL 2A SIGNAL SPECTACLES

N. Y. N. H. & H. Railroad

Figure 5

PLATE H-111

THE UNION SWITCH & SIGNAL CO.



CENTRIFUGAL FREQUENCY RELAY

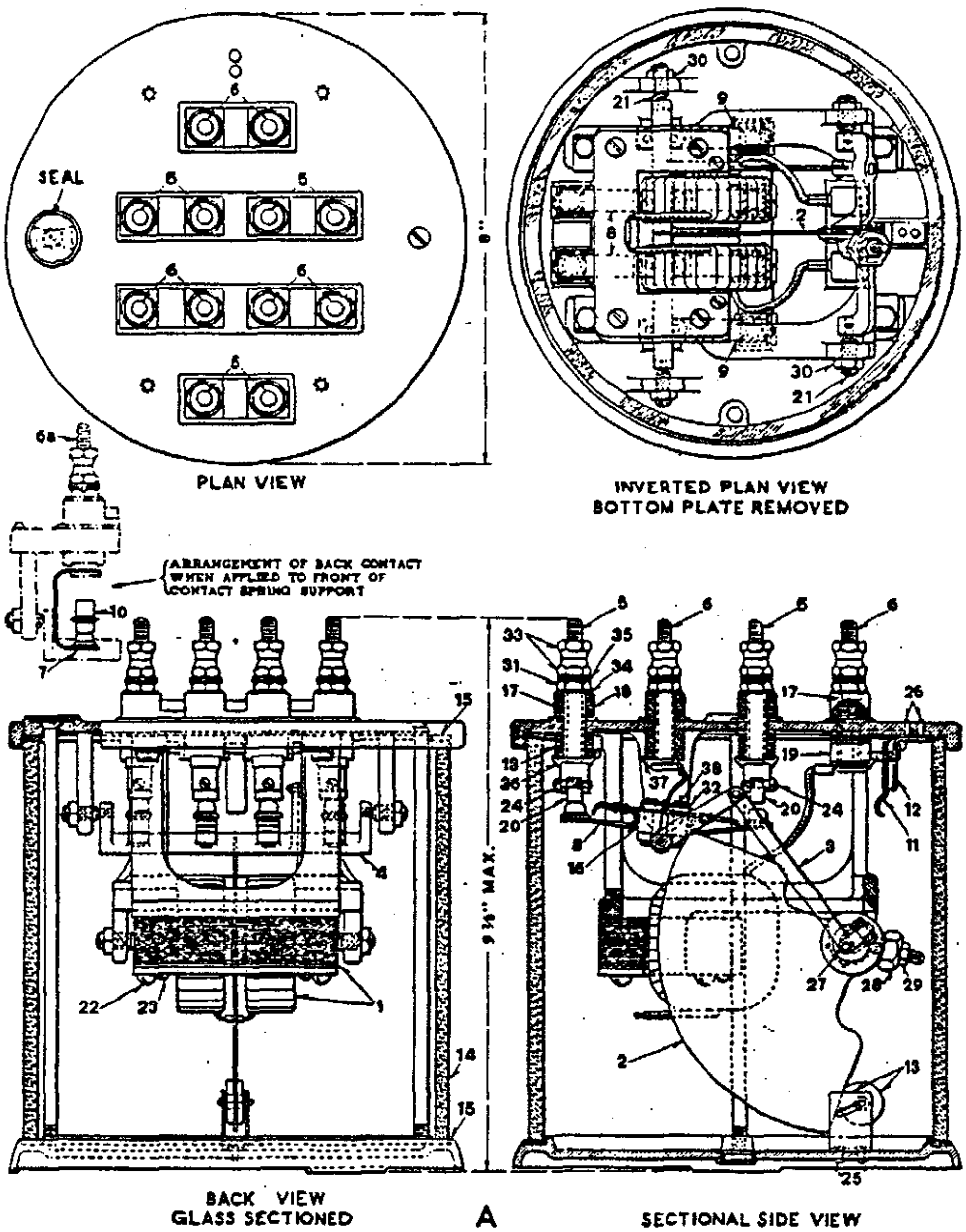
CENTRIFUGAL FREQUENCY RELAY

N. Y. N.H. & H. Railroad

Figure 6

PLATE H-101

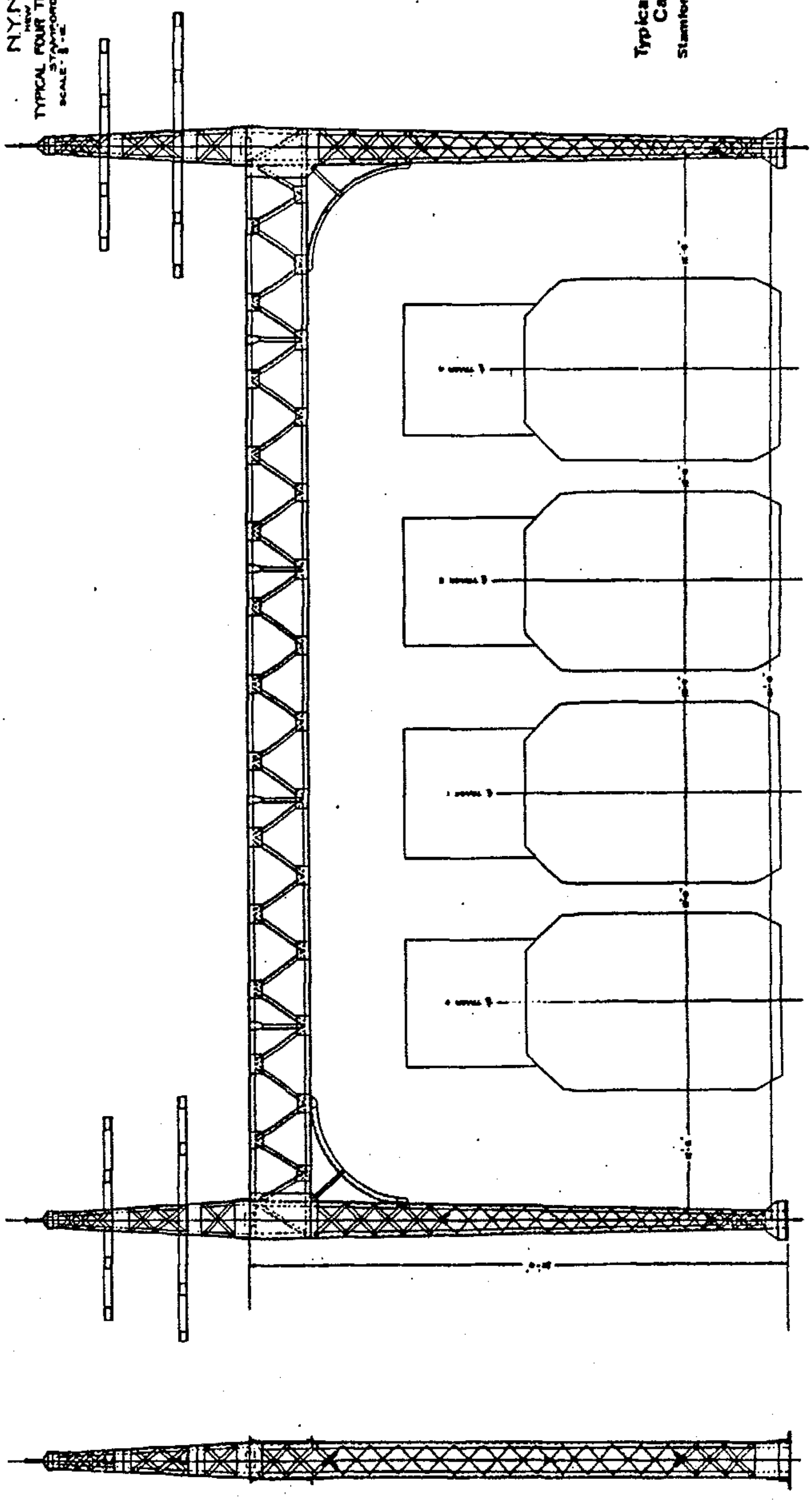
THE UNION SWITCH & SIGNAL CO.



VANE TYPE RELAY

VANE TYPE RELAY

N. Y. N.H. & H. Railroad



Typical Intermediate
Catenary Bridge
Stamford to New Haven

Figure 8